

Different responses to mega-trends in less favorable farming systems. Continuation and abandonment of farming land on the islands of Lesbos and Lemnos, Greece

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ARTICLE INFO

Keywords:

Land abandonment
Land use intensity
Marginal lands
Oral history interviews
Mediterranean agriculture

ABSTRACT

Farming systems in marginal or less favored areas of Europe have faced a multitude of challenges as a response to so-called “mega-trends”. A typical response has been land abandonment. The focus of this paper is on the farming systems of the Greek islands of Lesbos and Lemnos. These neighboring islands are geographically very similar but differ greatly in their farming systems, resulting in different responses to the same megatrends. While land abandonment is widespread in the small-scale olive groves of Lesbos, on Lemnos specialization towards animal and dairy products is more common. We performed land cover analysis and interviews with farmers in both areas, in two complementing rounds: one more quantitative that recorded recent changes and farmer rationales and a more qualitative one that investigated longer term trends and decision-making patterns. The analysis revealed that, among others, land ownership and inheritance patterns matter in both areas in different ways, leading to diverse trajectories. On Lemnos, as part of the traditional mixed-farming system (*Mandra*), land leasing is dominant, separating land users and landowners. Interviews also reveal the different symbolic capital, as olive trees on Lesbos are considered a family asset and not just a land use, something that cannot be said of the leased grazing lands on Lemnos. The market value of the different products is important, but the different trajectories also demonstrate how the rationales behind the responses to mega-trends can guide which trajectories will be dominant in the area. This article highlights the complexity and mix of local drivers and global trends that drive abandonment at both farm and the landscape scales and guides the formulation and application of agricultural policies and public resources for improved management of marginal areas.

1. Introduction

Despite rising global demand for farmland, agricultural abandonment is a widespread process, both in remote areas and in proximity to intensively used land (Kuemmerle et al., 2016; van der Zanden et al., 2017). Agricultural abandonment refers to a situation where “[the] human control over land (e.g. agriculture, forestry) is given up and the land is left to nature” (FAO, 2006). In Europe, abandonment is one of the dominant land use change processes (Plieninger et al., 2016; Terres

et al., 2015; Ustaoglu and Collier, 2018). In the Mediterranean in particular, it is considered as one of the dominant processes of land change (Levers et al., 2016; Sluiter and De Jong, 2007). It is a complex and multi-dimensional process (Dolton-Thornton, 2021) and results from different physical, environmental, social and economic factors (van der Zanden et al., 2017). Typically, land abandonment is one of the multifaceted trajectories of land change in an area, along with intensification, urbanization and niche market specialization that farmers may choose in order to avoid marginalization (Debolini et al., 2018). The

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impact of abandonment on biodiversity and landscapes have been described as both positive and negative (van der Zanden et al., 2017). Positive as it can lead to the return of nature (Fayet et al., 2022a), but at times it can have negative impacts on valued landscape features and landscapes as a whole (Debolini et al., 2018; Delattre et al., 2020).

An interplay of socioeconomic and biophysical megatrends can lead to land abandonment (Debonne et al., 2022). Some of these mega-trends include the globalization of agricultural production that has transformed many agricultural products into market commodities and reduced prices for some due to global transport and competition (Kienast et al., 2019). In response, farmers were forced to specialize and intensify, while abandoning low-yielding land (Lasanta et al., 2017). In mountainous, arid, or otherwise marginal regions, land abandonment has thus often become the dominant -but not the only- process of land use change (Levers et al., 2016). The lower competitiveness of marginal lands may be further exacerbated by climate change (Plieninger et al., 2016). In addition to globalization, demographic changes such as urbanization and increasing mobility have led to over-aging and labor shortage in rural areas (Quintas-Soriano et al., 2022). Fayet et al. (2022b) found three different broad trajectories after abandonment: The first one is the return to agricultural uses “where the land is managed again [...] with new economic and social activities”, including sub-processes such as landscape preservation and diversification of land uses with low-impact management activities. The second one is revegetation, the most frequent trajectory observed after abandonment leading to managed revegetation and restoration or spontaneous revegetation. The third one is urban transformation.

The Mediterranean in general, and mountain and island areas in particular, have been recognized as areas most affected by mega-trends leading to land abandonment (Fayet et al., 2022b; Jiménez-Olivencia et al., 2021; Levers et al., 2016). Islands in the Mediterranean were historically favored because access to the sea allowed integration into regional trade networks. However, after the industrialization of agriculture and the shift from regional to global trade networks, many islands became marginalized and faced declining populations, until the emergence of tourism in the later part of the 20th century. In Greece, the total number of farms on islands decreased by 40 % between 1961 and 2000, while the amount of arable land decreased by 75 % for the same period (Spilanis and Kizos, 2015). The main farming systems on Greek islands are small ruminant husbandry (sheep and goats) and olive cultivation. For animal husbandry, overall there is a separation of its complementarity with arable crops, which results either in complete abandonment of animal husbandry, or in its intensification and reliance not on grazing alone, but to imported feed (Kizos et al., 2013 for the context and Spilanis and Kizos, 2015 for statistical data). A notable exception is Lemnos, where the mixed system of arable crops and animal husbandry is retained (Dimopoulos and Kizos, 2020). For olive groves, the overall change on islands is slightly positive in the period of rapid changes (+ 4.5 %) (Spilanis and Kizos, 2015), but these represent farming systems that are very extensive with many part-time and hobby farmers that practice few if any practices other than pruning the trees and collecting the olives. Therefore, such systems (also encountered on Lesvos) can indeed be considered as extensive when compared to more intensive systems of Greece and the Mediterranean (Aranda et al., 2011; Gkisakis et al., 2018; Sofu et al., 2020).

The marginalization of agriculture on islands has been recognized by the EU and the Common Agricultural Policy (CAP). All Greek islands (except Crete) are considered as Less Favored Areas (LFAs), in which farmers under 65 of age receive a so-called “compensatory payment” for certain types of land uses (including cereals, olives, sheep/goat husbandry, but excluding e.g. vegetable production). Such subsidies, it has been argued, partially slowed land abandonment by supporting these marginal production systems (Delattre et al., 2020; Levers et al., 2018; Zavalloni et al., 2021).

However, many obstacles in the existing policy framework are reported. According to Fayet et al. (2022a) abandoned farmlands can

contribute towards species protection and land restoration, but there seems to be a “management gap” on the ground with a mismatch of available policies and abandonment. They also claim that “if abandoned lands are not integrated within biodiversity and climate policies, there is little chance of uptake on the ground and opportunities for (re-)management risk being missed”. Policy responses for rural development and especially the challenge of translating EU policies to abandoned lands is associated with the areas where land is abandoned, often with declining populations and small “interest” of the CAP towards them (Zavalloni et al., 2021). Other pressing issues in this regard are how to ensure that farmers are informed about policy options and how to better coordinate the various regional development and agricultural policies (Fayet et al., 2022a). There is therefore a need to study the responses of farmers in such marginal areas within this framework of global trends, policies and local histories and particularities.

In this paper, we analyze two different extensive farming systems on two Mediterranean islands and their changes to (a) present the different trajectories of land use changes among and within each case study; with a focus on abandonment; (b) discuss the rationale behind these differences. We utilize different types of data: land cover change data and data from interviews. The overall objective is to explore i) how some of the dominant trends in farming systems - in particular marginalization and abandonment - manifest themselves in systems that are less favorable for agricultural scale enlargement, and ii) whether different regions that share a corresponding EU setting react similarly to the said megatrends. For this end, we investigate farming systems on two islands in which agricultural production and workforce have been decreasing over the past decades. Also, both study areas are estimated to have a high risk of land abandonment according to a recent land use modeling study (Castillo et al., 2021). These systems are different as one involves permanent plantations of olives, a typical Mediterranean tree, while the other represents a mixed system of arable crops and animal husbandry; similar in the sense that both study areas are rather extensive systems when compared to other comparable land uses in Greece, the Mediterranean and Europe.

2. Methods and Data

2.1. The case study areas

The case study areas are on two islands, Lesvos (1600 km²) and Lemnos (477 km²) of the North Aegean Region, Greece (Fig. 1).

On Lesvos, the case study landscape is in Gera, a municipality in the south-eastern part of the island (Fig. 1). The landscape of the area is hilly and is dominated by terraced, continuous olive groves (as high as 550 m a.s.l.), while only little other land is managed for other agricultural purposes. Some plantations have been abandoned or neglected in recent decades. According to official data (ELSTAT, 2022), Gera’s population has declined in the last decades (-37 % from 1951 to 2011, and -13% between 2001 and 2011), in line with the trend for the whole island. The population is also ageing, with more than a quarter of its population older than 65. The economy of the area depends on agriculture, almost exclusively on olive oil production, and to a lesser degree, on tourism and the public sector.

Lemnos is a smaller island than Lesvos. Unlike most Aegean islands, it is relatively flat (highest point 430 m a.s.l.), with more rugged relief in its western and northern parts, dominated by phrygana and short grasslands grazed by sheep and goats. The case study landscape lies within the area of the municipalities Kontias, Portianou, and Tsimandria (Fig. 1) in the southwestern part of the island that includes the plain of Kontias, an area of arable crops, as well as the surrounding hills, dominated by phrygana grazing lands for sheep and goats. As on Lesvos and other Aegean islands, the population of Lemnos reached a peak in the early 1950s (exceeding 24,000 residents), facing sharp decline until the 1980s (with a record low of 15,700 in 1981), to slightly recover in the past 30 years (approximating 17,000 in 2011). As on Lesvos, the

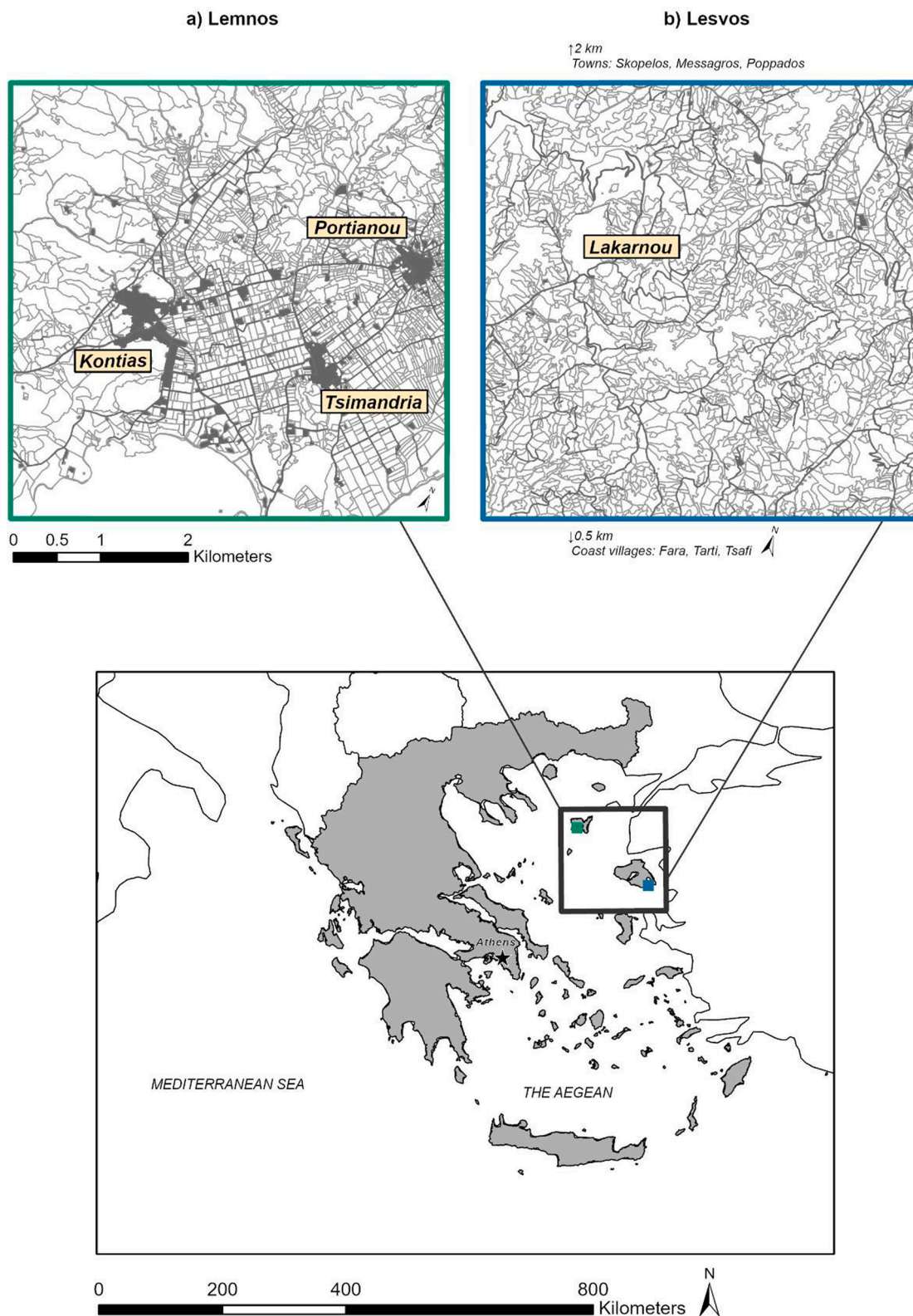


Fig. 1. The case study areas on Lesvos and Lemnos Islands. Agricultural parceling is shown for both islands in (a) and (b). Settlements are depicted in grey in the detailed maps.

population is ageing, with 23 % older than 65 (ELSTAT, 2022). In the case study area, farming is the most important economic and social activity. The farm types of the area are mixed farms combining cultivation of crops and sheep husbandry or farms oriented to arable farming only (Dimopoulos et al., 2018).

The farming systems that we examined on these islands are olive groves for Lesvos and the mixed arable crops - sheep husbandry for Lemnos. Both systems represent extensive systems in marginal areas. Therefore, the comparisons are not only between these two systems, but more importantly both against more intensive systems in non-marginal

areas. Another reason is related to the spatial context. Both areas are islands with slightly different geomorphology (Lesvos being more hilly) but similar soils. As islands, they have faced similar socioeconomic changes in the last decades and in both, the overall population decreased significantly until the 1990s, with less and less willing to engage with farming as a livelihood (Spilanis and Kizos, 2015). In this context, the comparison of these two systems can provide insights into if and how and why there are differences in the trajectories of recent farm change despite spatial similarities and if we can explain these based on what the farmers say.

2.2. The research approach

The research approach followed four steps: (a) definition of trajectories of land use change and operationalization at farm and landscape scales; (b) quantitative analysis of farm-level management and structure changes with farmer interviews; (c) land cover and landscape change analysis from aerial photographs and satellite imagery; and (d) qualitative oral history interviews to reveal farmers’ perceptions on observed farm and landscape scale trajectories. While the quantitative farmer interviews and landscape change analysis focused on the period from 2000 to 2020, the oral history interviews went further back in time to elucidate the broader historical contexts. We also used secondary statistical data to cover gaps and broaden the time frame. Our approach considered both the farm scale, as the key economic unit and the scale were land managers take decisions, and the landscape scale, which is relevant for social and environmental sustainability outcomes (Helfenstein et al., 2020).

2.2.1. Characterization of trajectories

For each case study and at both farm and landscape scales, we considered four trajectories of land use change, following Heider et al. (2021), who employed a similar method in Spain:

a) Persistence: All cases where land cover and farm management has remained the same.

- b) Intensification: All cases where fields were used more intensively in terms of irrigation, fertilization, plant protection, energy, and labor, or where more extensive land covers were transformed to more intensive land covers (e.g. extensive grasslands to cropland).
- c) Niche market specialization: Diversification at the farm-level and appearance of new agricultural land uses at the landscape scale.
- d) Marginalization: Cases where inputs and land management are reduced, a precursor to or early stages of land abandonment.

These different trajectories affect the separate fields of the farms, and the configuration of these trends at the landscape level provides the overall outcome in each study area (Fig. 2).

2.2.2. Quantitative farm structure analysis

We performed structured face-to-face interviews with 20 active farmers from each case study area to determine changes in farm structure and intensity. The questionnaire probed general farm characteristics as well as livestock, arable and permanent crop production. Following Helfenstein et al. (2022), each question had two parts. First, farmers were asked about the current situation of the farm (e.g., how many pesticides applications are applied on the main crop?). Second, farmers were asked how the current situation compares to the situation 20 years ago (e.g., how many pesticide applications were applied 20 years ago?). Previous applications of this approach have shown that reported relative changes agree with actual management changes (Helfenstein et al., 2022). While farmers may have trouble recalling absolute values of inputs (such as kg of N fertilizers applied per ha) because they often rely on practical rather than scientific units (e.g. one barrel of slurry), they were usually confident in estimating relative increase or decrease, since the farm characteristics and management variables questioned are elementary for their work as farmers. However, if farmers were unsure, they could answer, “don’t know”. All interviewees provided their informed written consent. The interviews were conducted in the fall of 2020.

From this information we calculated eleven indicators of farm structure and change (Table 1) related to farm developments (farm area, livestock units, livestock and crop diversity, feed import), social (age of

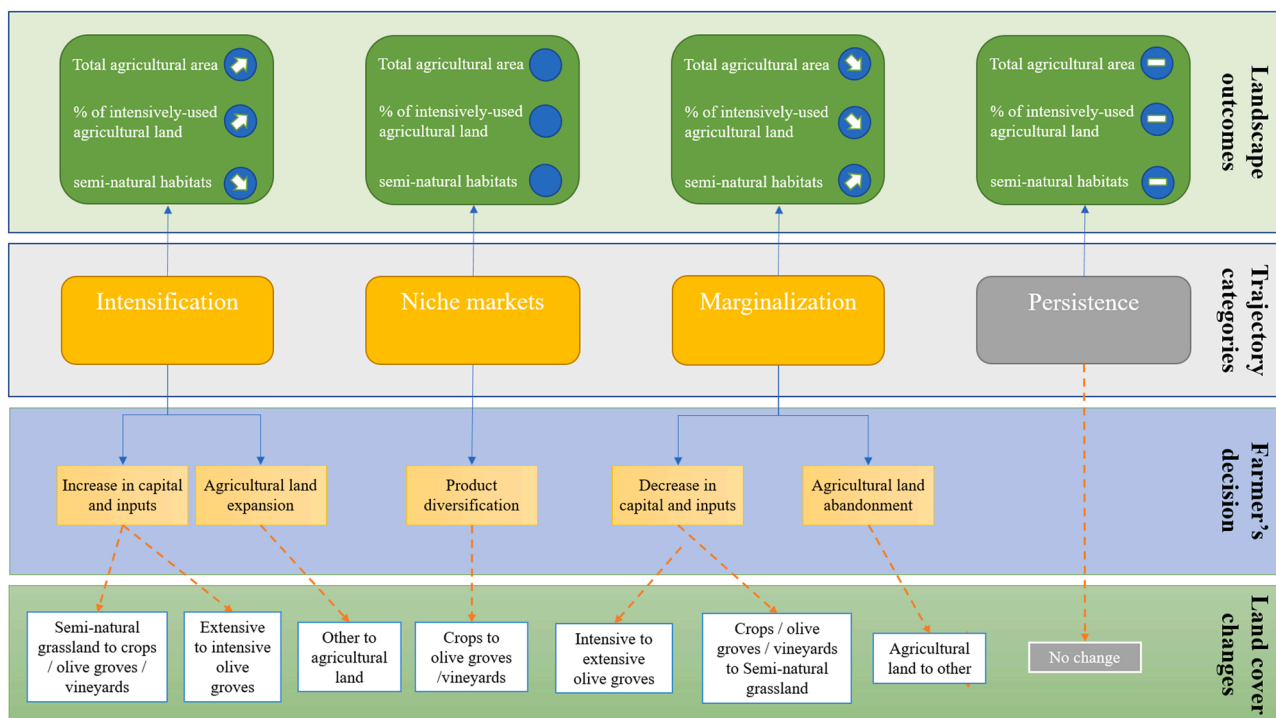


Fig. 2. Characterization of trajectories.

Table 1

Indicators assessed in the quantitative farm-structure analysis, and the relationship between individual indicators and trajectories of land use change. The direction of change and weight of the indicator were used to calculate alignment of each farm with each trajectory.

Category	Indicators	Marginalization Change direction	Persistence	Intensification	Niche markets
Farm-scale development	farm area	–	0	++	NA
	livestock units	–	0	+	NA
	crop diversity	NA	0	–	+
	livestock diversity	NA	0	–	+
	feed import	–	0	++	–
Social	% old farmers (> 65 years old)	++	0	+	–
	% old farmers (> 65 years old) without successor	++	0	–	–
Economic	production trend	–	0	++	NA
	N intensity	–	0	++	–
Environmental	pesticide use	–	0	++	–
	livestock density	–	0	+	–

Direction of change and weight: (–): negative, 0: neutral, (+): positive, (++): very positive, NA: not applicable.

farmers and succession), economic (production trend) and environmental aspects of farm operation (N fertilizer use, plant protection use, and livestock density). To translate developments in individual indicators into land use change trajectories, we determined the direction of change and its weight for each trajectory (Table 1).

2.2.3. Land cover and landscape change analysis

Mapping of land use was based on image interpretation of orthorectified aerial photographs using geographic information systems (ArcGIS) for an area of 25 km² for each island and was conducted in two points in time between 2000 and 2020, based on availability of data. For Lesvos (Table 2), the first time of investigation was 2005 (aerial pictures) and the second in 2017 (satellite imagery). For Lemnos the first time was 2003 (aerial pictures) and the second again in the year 2017 (satellite imagery) (Table 2). For each time step, the image was first segmented (see Fig. 1. A and B). Then, land cover was classified following the European Nature Information System (EUNIS) habitat classification (EEA, 2019). We expanded this classification with location specific land use types that were known from other studies (Biel, 2002; Kizos et al., 2018) to occur in the respective case study site. This resulted in nine land use classes for Lesvos and ten for Lemnos (Table 2).

To capture the process of gradual olive grove abandonment on Lesvos, we differentiated between intensively and extensively managed olive groves based on the presence or absence of undergrowth vegetation. While in intensively managed olive groves on the island, typically the ground between the olive trees is bare or covered by dry grass due to mechanical clearing or spraying, in extensively managed olive groves shrubs and small trees develop between the olive trees, due to lack of management from farmers (Kizos et al., 2010; Kizos and Koulouri, 2010). To complement classification into intensive and extensive olive groves via aerial photographs, an additional NDVI analysis was performed. A series of cloud-free Landsat images (30 × 30 m resolution) were selected for the investigation area by a satellite viewer (SM Table 3). This was accomplished for similar days of three months in two consecutive years to consider the increasing dryness of the vegetation on the one hand, but to avoid a year of extreme drought or wetness on the other hand. The mean of the satellite bands was then calculated for each month in Google Earth Engine and applied in a WekaXmeans cluster analysis where similar NDVI values were grouped without requiring any training data (Pelleg and Moore, 2000). This resulted in a homogenous NDVI value and clusters, which assisted classification of olive groves on Lesvos.

Table 2

Data sources and land use classes for the study sites.

Study site	Land cover class	Land use	Year	Data source	Resolution
Lesvos	<ul style="list-style-type: none"> • water, • forest, • crops, • sealed area, • semi-natural grasslands, • barren land • olive groves 	Olive groves: <ul style="list-style-type: none"> • Intensively managed (absence of shrubs in the understory) • extensively managed (presence and dominance of shrubs in the understory). 	2005	Aerial picture by Hellenic Military Geographical Service, Supported by 2005 satellite image from Google Earth Pro.	1 m after georeferencing
			2017	Maxar satellite imagery basemap from ArcGIS	31 cm
			2003	Aerial picture by the Hellenic Military Geographical Service	0.9 m after georeferencing
Lemnos	<ul style="list-style-type: none"> • water, • wetlands, • forest, • crops, • vineyards, • sealed area, • semi-natural grasslands, • barren land, • field margin vegetation (extensively managed strip of grassland with a minimum width of 5 m) • abandoned land (abandoned agricultural land with a succession from semi natural grasslands to shrublands). 		2017	Maxar satellite imagery basemap from ArcGIS, composed of a picture section from February 2017 and another from June 2017.	31 cm

Table 3

Changes in farm-scale indicators. Table shows the reported median for 2000 and 2020 the p-value from a Wilcoxon-rank test (statistically significant differences ($p < 0.05$) are **bold**); and the sample size (n) for the test.

	Indicator	Unit	LES				LIM			
			2000	2020	p-value	n	2000	2020	p-value	n
Farm-scale development	farm area	ha	4.8	5.3	0.075	19	30	40	0.027	19
	livestock units	LU	0.52	0.02	0.402	20	50.2	65.27	0.862	19
	crop diversity	count	1	1	0.343	19	5	3	0.003	19
	livestock diversity	count	1.5	0.5	0.07	20	6	6	0.955	19
	feed import	%	47.5	80	0.586	7	45	70	0.006	18
Social	% old farmers	%	NA	35	NA	NA	NA	10.53	NA	NA
	% old farmers w/out successor	%	NA	15	NA	NA	NA	5.26	NA	NA
Economic	production trend	%	NA	66.84	NA	NA	NA	66.84	NA	NA
	N intensity	kg N ha ⁻¹	78.8	76.0	0.263	15	55.5	50.0	0.638	19
Environmental	pesticide use	count	7	5	0.013	19	0	0	NA	18
	livestock density	LU ha ⁻¹	0.48	0	0.069	18	2.42	1.38	0.029	18

This resulted in land use maps for the two time-instances. For land conversions, land uses were cross tabulated, showing the transformation from each land use type to another in the actual change in area (Helfenstein et al., 2022). This was conducted by an intersection of the respective land use classifications. Eventually, the respective change in areas was transformed in selected trajectories (SM Table 1). Relative changes were calculated by the natural logarithm (Törnqvist et al., 1985).

2.2.4. Qualitative analysis: oral histories and farmer interviews

The second round of interviews was used to verify the findings of the quantitative research and place the trajectories in a longer-term land use history narrative. We conducted oral history interviews (OHI) with farmers who have been working on their farm for a long time. OHI have been used by historians since around the second half of the 20th century (Wierling, 2003) to record and research everyday histories and the experiences of social groups that leave little trace in written documents (Schaffner, 1988). Recently, this method has also been used in research on landscape change (Bürgi et al., 2017). We used a semi-structured questionnaire. The first part of the questionnaire inquired personal experiences of life on the farm. The second part focused on changes on the farm and their driving forces.

A total of 21 face-to-face oral history interviews were conducted with farmers from Lesvos and Lemnos, aged between 59 and 88 years in the fall of 2020. The interviews were recorded and transcribed. The local interviewees were able to build up a relationship of trust with the interviewees. Participants were recruited via a snowball sampling method, whereby the local knowledge of the interviewees was a decisive advantage. The interviews took place either on the farmer's farm or in the local coffee shop (traditional meeting points in rural Greece). The oral history interviews were transcribed and then coded according to seven main changes observed during the interviews with the active farmers (see in Sections 2.2.2 and 3.1). The coded topics were then analyzed for recurring themes.

3. Results

3.1. Changes of farm structures

In terms of farm-scale developments, more change is evident on Lemnos than Lesvos over the past twenty years. While average farm area increased on both islands, this trend was only significant for Lemnos, where median farm area increased by +33% ($p = 0.027$, Table 3). While livestock are more important for the farming systems on Lemnos, total livestock units per farm did not increase in either case study. However, crop diversity per farm decreased on Lemnos ($p = 0.003$), suggesting specialization. Despite growing farm area and stable livestock numbers, the proportion of feed imports increased on Lemnos ($p = 0.006$). Hence, we see indications of farm growth and

specialization on Lemnos, whereas farm structure seemed to be in line with persistence on Lesvos.

The social indicators revealed a farmer aging and succession crisis on Lesvos: older farmers (> 55 years old) comprised 35% of all interviewees, and old farmers without successors comprised 15% of all interviewees. On Lemnos both indicators were around three times lower (Table 3). A structural difference is evident when the ratio of owned vs. leased land is considered: on Lesvos the large majority is managed by the farm owner, while on Lemnos most farmers had more leased than own land.

The main product for farmers on Lesvos are olives. On Lemnos the main farm products were milk and lamb meat. Reported average price received for the main product decreased by almost –40% on Lesvos, while it decreased by –18% on Lemnos. Meanwhile, farmers on both islands reported increasing production of the main product. Off-farm work played an important role on some farms in both case study areas but did not change significantly over the study period (Table 3).

There was large variability in N intensity on Lesvos. While some reportedly applied up to 200 kg N ha⁻¹ other applied none, and while some increased, others reduced application over the study period. Due to this large variability, there was no significant trend, though generally N intensity seems to be higher today than 20 years ago (Table 3). However, the number of plant protection/pesticide applications decreased significantly on Lesvos ($p = 0.013$). On Lemnos on the other hand, N intensity remained constant. Farmers reported not using any fungicides and insecticides, while it was confirmed in the oral history that herbicides are in use since the 1960's. Due to increasing farm area and stable animal numbers, median livestock density decreased by 43% on Lemnos ($p = 0.029$).

3.2. Trajectories of change at the farm-scale

The trajectories of change that are derived from the changes of farm structures of the farms of our sample (Table 4) were determined by the values of the indicators and the assumed direction of change for each indicator (Table 1). The percentages of farms in each category correspond to the dominant trajectory for each farm, as there are cases where farmers report that one or more of their fields can be classified in one trajectory while a couple of fields in another. The results show that marginalization is more dominant on Lesvos (along with niche markets), while on Lemnos intensification is by far the most dominant trend (68% of the farms), followed by marginalization. Very few farms have reported persistence in terms of inputs (a finding that is not evident in the analysis of land cover in the next section).

3.3. Land cover and landscape outcomes

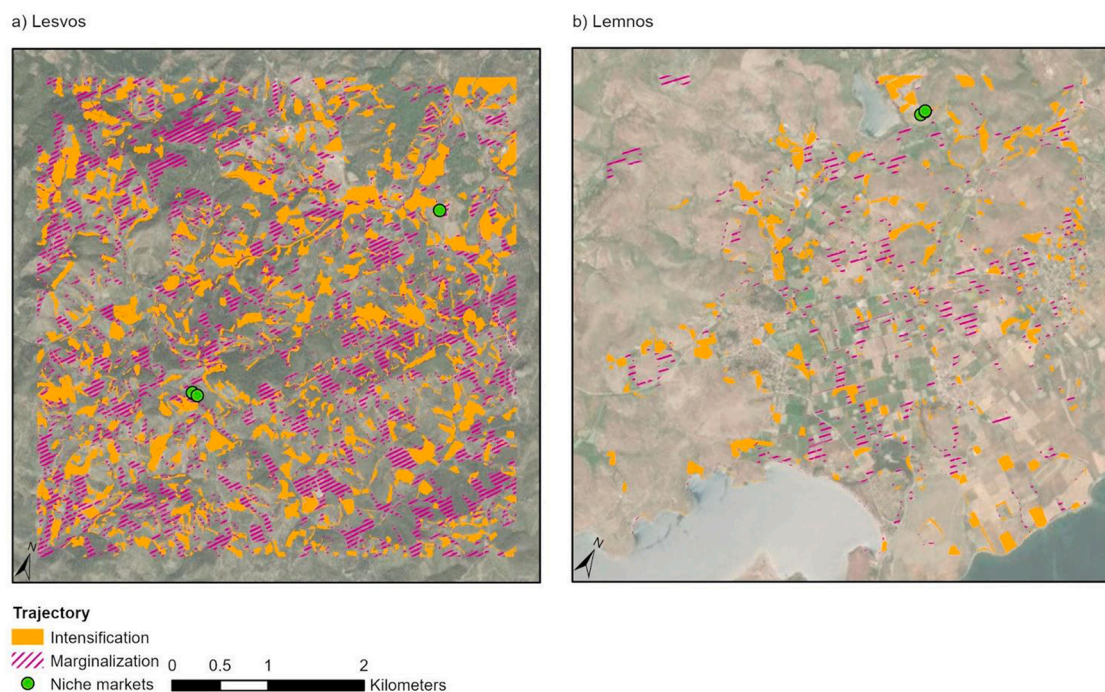
Landscape mapping on Lemnos (Fig. 3) revealed a slight decrease in total agricultural area by –1.8% from 2045 to 2009 ha. Total

Table 4

Dominant-farm level trajectories in each case study site. The table shows the median agreement and the % of farms aligning most closely with each trajectory (marginalization, persistence, intensification, niche markets).

	Marginalization		Persistence		Intensification		Niche markets	
	Median	% Of farms in trajectory*	Median	% Of farms in trajectory*	Median	% Of farms in trajectory*	Median	% Of farms in trajectory*
Lesvos	68.2	35.0	63.9	0.0	60.9	30.0	75.0	35.0
Lemnos	50.0	21.1	44.4	5.3	71.9	68.4	55.0	5.3

* Highest agreement with this trajectory.



Source: based on aerial data from a) https://www.gys.gr/index_en.html (2021) & Satellite imagery basemaps from Esri (2017) b) https://www.gys.gr/index_en.html (2021), Google Earth (2005) & Satellite imagery basemaps from Esri (2017)

Fig. 3. Trajectories of change on Lesvos (a) and Lemnos (b). What is not marked represents persistence. The appearance of niche market land covers (vegetable productions on Lesvos and vineyards and olive groves on Lemnos) are depicted with green dots.

agricultural area on Lemnos covers crops, vineyards, semi-natural grassland, intensive olive groves and field margin vegetation. The proportion between intensively and extensively used agricultural land remained stable with a share of 42 % and 58 % respectively of the total agricultural area in 2017. Meanwhile, average field size decreased significantly from 0.54 to 0.49 ha. Semi-natural grasslands are still predominantly found on the hilly plateau in the western part, whereas lowlands are used for crop production such as cereals, clover and alfalfa. However, semi-natural grassland decreased slightly by -3.7% from 1208 to 1164 ha and so did the area used for crop cultivation from 828 to 819 ha. Intensive olive groves, which play only a minor role on Lemnos, expanded by $+143\%$ from 3.7 to 16 ha, along with vineyards ($+38\%$ from 2.7 to 4ha). In addition, forest areas have expanded from 38 to 48 ha ($+23.7\%$) as well as abandoned land from 9.7 to 33.2 ha ($+122.7\%$). The area of sealed surface also increased from 131 to 143 ha ($+8.9\%$).

For Lesvos, landscape mapping showed a slightly more pronounced decrease in total agricultural area by -3.7% from 1957 to 1886 ha. Olive production dominates, but semi-natural grassland and patches of crops were also present. While the proportion of intensively used agricultural land remained the same, the area of extensively used agricultural area decreased by -6.8% , but is still the predominant land use type, accounting for 54 % of the total agricultural area in 2017. Forest

area increased by $+12.9\%$, following abandonment of olive groves. Sealed areas increased by $+8\%$. The share of semi-natural grassland decreased slightly by -2% from 116 to 113 ha. Comparing the two olive grove management systems, no change was observed for intensive olive groves. In 2017, an area of about 870 ha was used for intensive olive grove production. The area of extensively managed olive groves, on the other hand, decreased by -7.3% from 964 to 895 ha. Crops still play only a minor role in land cover on Lesvos. Small patches of vegetables are scattered over the entire study site, but their cultivation area increased by $+155\%$ from 1.3 to 5.9 ha.

In terms of land use change trajectories at the landscape-scale, the most widespread process was persistence on both islands (Table 5). On Lemnos, no change was observed on 1745 ha, which accounts for 85 % of the total agricultural land. On Lesvos, persistence rate was lower (56 %), since there was considerable change from intensively to extensively managed olive groves and vice versa, reflecting the gradual shrub encroachment on some plots, and the re-clearing of other plots. Overall, however, both intensive (-60 ha) and extensive (-108 ha) olive groves were lost to forest, suggesting net marginalization and land abandonment.

Table 5

Trajectories of changes/persistence from landscape analysis of the case study areas on Lesbos and Lemnos.

Process	Lesbos			Lemnos		
	ha	% of total area	% of change	(ha)	% of total area	% of change
Intensification	448	17.90	44.9	124	4.95	35.5
Marginalization	479	19.1	48	120	4.80	34.4
Niche markets	0.11	0.01	0.01	9.40	0.4	2.70
Other changes	71	2.8	7.1	95	3.8	27.4
Change	997.	39.9	100.00	348	13.94	100.00
Persistence	1457	58.3	–	2123	85	–
Persistence*	1094	43.7	–	1745	69.9	–
Total area	2500	100.00		2497	100.00	

* Only agricultural area – excluding water, wetland, forest, settlement, barren land, field margin vegetation, abandoned land

3.4. Explanatory narratives

Based on the trends of farm structure in the last 20 years, seven observations that correspond to intensity indicators were investigated using material collected in the oral history interviews (OHI, Table 6, more details from the OHI can be found in SM Table 2).

Many of the observed changes in Lemnos from the quantitative farm structure analysis were reflected as well in the oral history interviews. In recent decades, the importance of animal husbandry has steadily increased and replaced the sale of crops. This increased focus on animal husbandry has also impacted crops: whereas in the past a variety of crops was important, today it is often fodder crops such as clover or barley that are exclusively grown: “Look, for example, before here there was no clover here, now the area of Kontias has a lot of clover and they also put some corn.” (lem_f8). This development went along with a change in sheep breeds that took place from 2000 onwards. Sturdy but less

productive indigenous breeds were replaced by high performance breeds from other areas of Europe (France, Germany). However, these animals require more care in terms of specialized feed, medical care and housing. It is very likely that the increased feed imports are related to these developments (Table 3). As a sheep farmer remarked: “They are better now, the locals were small, after the Mytilene’s sheep, now the lacons [French sheep] came, the breeds changed, we had locals back then. You cannot now compare the local sheep with the lacon, the lacon produce but they can only stay in the stable. No, the lacons are sensitive, they are not like our old ones, the locals, hard sheep, they could stand the drought and everything.” (lem_f5).

While more animals need more land, the increase in farm area is also related to land tenure and land availability: Lemnos experienced a wave of emigration in the 1980s, which had an impact on the traditional farming system and made it cheaper to rent land. Thus, compared to the past, reportedly the number of farmers is smaller and they seem to have more land at their disposal. According to the OHIs, this “land surplus” can lead distant pastures to disuse, while formerly inaccessible and cultivated fields are now used as pastures. It also comes out that the historically strong tradition of leasing most of the land facilitates more dynamic changes in farm sizes.

On Lesbos, the current low olive oil price is used by the farmers as an explanation for many changes. Olive oil provided a very good income in the 1960s and 1970s according to farmers and later through state subsidies (meaning the Common Agricultural Policy support). Based on the answers of the interviewees, the price of olive oil has been at an all-time low in recent years. In the perception of the farmers interviewed, one reason for this is that mechanization is only possible to a limited extent on Lesbos due to the topography, e.g: “We are not like Spain which has mechanized cultivation, here in the mountains how will this be done? We have no roads here... the fields exist only thanks to the previous generations who had a passion and desire for work, but at the same time it was a need to live, so they cultivate them!” (les_f9).

Table 6

Observations that correspond to farm structure indicators, the trajectory they indicate and the evidence from the OHI interviews.

Farm structure indicators	Relevant for Lesbos	Relevant for Lemnos	Trajectory	Explanation from oral history interviews
Rising feed import		x	Intensification	<ul style="list-style-type: none"> Adoption of more productive animal breeds around 2000 Increasing importance of intensive animal husbandry in the economic orientation of farms.
Decreasing crop diversity		x	Intensification	<ul style="list-style-type: none"> Specialization in livestock production encourages the cultivation of fodder crops instead of a wide range of arable crops as in the past. Due to migration and old farmers without succession, land availability has risen in the last forty years.
Increasing farm area		x	Intensification	<ul style="list-style-type: none"> Farmers today have bigger herds for which more space is needed to let them graze. Historically on Lemnos many people rent the majority of their land. In addition, some made use of subsidies to invest into more owned land. Due to low olive oil prices, not all farmers find it profitable to invest in fertilizers.
High variability in N-input	x		Marginalization/Intensification	<ul style="list-style-type: none"> The topography of Lesbos can determine where olive groves are more cultivated (flat areas) or less (hilly areas): Like N-input, investment in crop protection products is often not considered profitable.
Decreasing pesticide input	x		Marginalization/Niche markets	<ul style="list-style-type: none"> Rise in organic farms – partly to achieve higher profitability, partly also to obtain subsidies from abandoned olive groves. In recent years, the price of olive oil has steadily declined, which greatly affected the motivation of farmers to continue producing and investing.
Decreasing olive oil prices for farmers	x		Global trend; can lead to marginalization, niche farming or intensification	<ul style="list-style-type: none"> Due to terrain, it is not possible to mechanize olive production as much as in other places. Farmers perceive to only have the option to sell to a handful of traders that have the same (low) price. Many descendants have studied and/or got another occupation and thereupon left the island or Greece.
Farmer aging & successor	x	x	Marginalization/Persistence	<ul style="list-style-type: none"> It is believed that the reason for this is no visible future in the “olive oil” business. Many observe more overgrown landscapes and a declining population in small villages as a result.

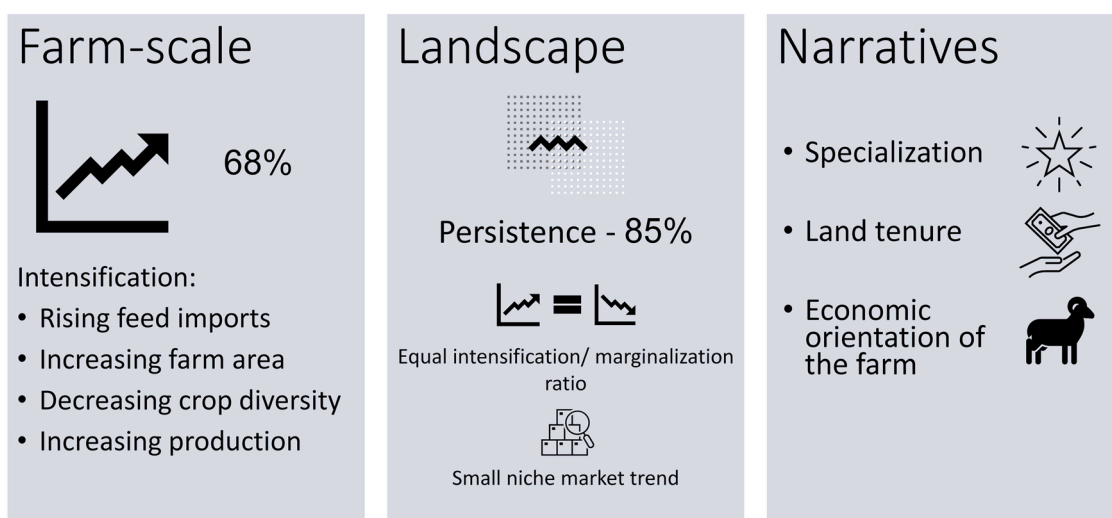
It is further often mentioned that until a few years ago, people could choose to sell their olive oil to a cooperative or to a private trader. Since most cooperatives failed, older farmers see it as the only option to sell to private traders who keep prices stable all over the island. Pesticides and fertilizers can also be seen as capital investments, the use of which has often not paid off in recent years leading towards a decrease or a polarization of the input of additives. It is also mentioned that the olive groves that are least maintained and least invested in are in the hillier and more inaccessible parts of Lesvos. Two farmers comment: “I fertilize a little now, only the lowlands and after pruning! I still use complex fertilizer with trace elements!” (les_f7); “People now are looking to get as much as they can without using herbicides, due to the low price of the olive oil it is not profitable.” (les_f4). Some farms have converted to organic, however, it is said that some use this as an excuse to receive subsidies while

abandoning their olive groves:

“The saddest thing is that some have joined the organic for the subsidy and have completely abandoned their fields.” (les_f6).

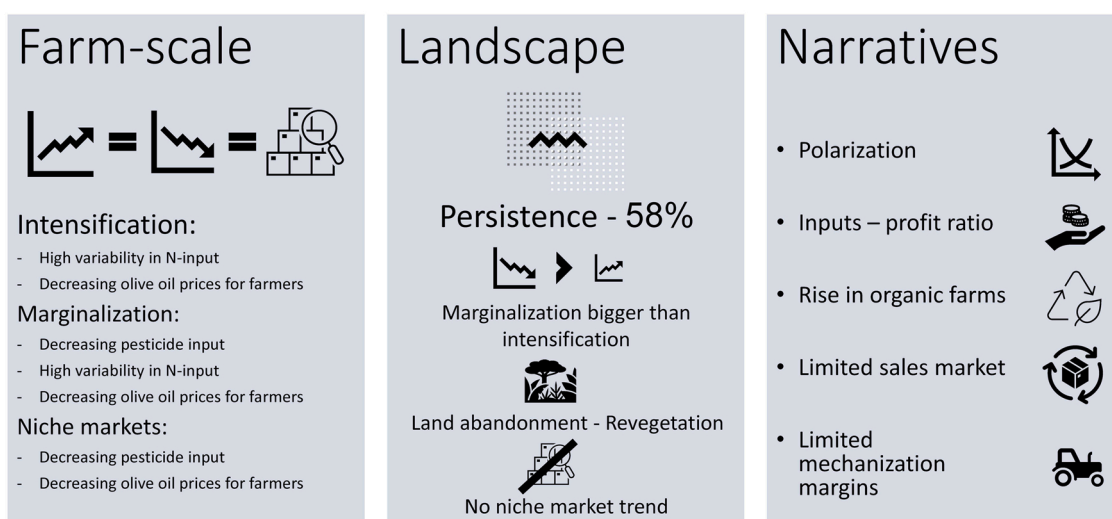
Although on both islands some farmers complain about the ageing and succession problems and the related consequences, this issue is more pervasive on Lesvos, where older farmers experience “dying villages” and abandoned olive groves in the hills, while on Lemnos it is often mentioned that unused land is overgrown with astivi (*Sarcopoterium spinosum*, a common shrub): *Those that are inaccessible and without roads... plus old people as we said who do not have someone to replace them and they just rent them to someone to go and pick the olives but not to cultivate them!* (les_f9); and “They used to cultivate the mountains, with

Lemnos



A: Synthesis for Lemnos

Lesvos



B: Synthesis for Lesvos

Fig. 4. Comparisons and synthesis of the findings from the different research approaches for Lemnos and Lesvos.

oxen, they cultivated them with the oxen and they produced barley, while now it is barren, “Astoivies”, not even a goat can stand to graze.” (lem_f10).

4. Discussion

4.1. Relevance of the approach

In this paper we recorded the different trajectories of land use changes among two case studies where similar changes as responses to mega trends were expected to occur, especially regarding abandonment. We followed a mixed research approach combining quantitative land cover analysis, quantitative farm structure analysis and qualitative analysis of oral history interviews to frame and explore more dimensions of the changes. This mixed approach (see also Kizos et al., 2018) has revealed more similarities and differences than would be visible if we employed a single approach, especially for three issues: how the farm and the landscape levels of change (or persistence) interact, how to include intensification (or extensification) in macroscopic analysis of landscape change, and how to frame national and global trends locally in the decisions of the farmers. A longer period could provide even more depth in the processes by gaining an understanding of the long-term dynamics of agricultural development and its drivers. Nevertheless, the approach yields some very valuable insights for such cases when compared to other similar land uses in Greece, the Mediterranean and Europe.

4.2. Comparison and synthesis

The cross tabulation of all findings for Lemnos (Fig. 4A) mark a mismatch between the landscape and the farm scales. While intensification is the dominant trajectory at the farm scale (for 68 % of the farms), the landscape is mostly characterized by persistence (close to 85 %) observed in the landscape change analysis. This specialization, scale growth, and intensification at the farm-level likely result from the efforts of farmers to compete in an increasingly globalized market (van Vliet et al., 2015; Kienast et al., 2019). Furthermore, this observation could be strengthened by a bias in the sample, as only active and thus successful farmers were interviewed. The questionnaires revealed that the intensification processes at the farm-scale are mostly related to the livestock sector (increasing livestock numbers and higher share of feed import) and average farm area. This agrees with the OHI findings where the increasing importance of intensive animal husbandry in the economic orientation of farms seems to have led to farm livestock specialization expressed through higher livestock numbers and a change from local to more productive animal breeds. The specialization on livestock also led to decreased crop diversity, as more fields had to be used to produce animal feed. Nevertheless, feed imports also increased. The intensification of the livestock sector on Lemnos reflects general patterns apparent through much of Europe, though at a lower level of intensity than in many other regions (Domingues et al., 2018). In other words, though livestock production has intensified, we did not see extreme concentration and specialization into mega-stables (with 500 or more livestock units), as is common in other parts of Europe (Debonne et al., 2022). Also unlike in other parts of Europe and other Greek islands experiencing intensification of the livestock sector, on Lemnos the processes are not visible at the landscape scale, giving the impression of persistence at the landscape-level.

On Lesvos (Fig. 4B), land management is less dynamic, which could be related to the fact that relatively little land is leased and olive trees are considered a long-term investment. Also, scale enlargement is not possible due to limited opportunities for mechanization. Thus, intensification is only possible to a limited degree, pushing farmers either into a niche market, such as converting to organic production or growing vegetables for local consumption, or land abandonment. Accordingly, marginalization is the dominant land use change process on Lesvos (Table 5). The prevalence of marginalization on Lesvos, but not on

Lemnos, even though they were both predicted to have high levels of land abandonment (Castillo et al., 2021), highlights the importance of deepening our insights on underlying processes through case study research to further improve land use models. Looking into the niche market at the farm scale it seems that some farmers reduce the use of pesticides and chemical fertilizers in the management of their olive groves, a change that cannot be captured through remote sensing. In the OHI results, these trends are linked with a turn to organic farming but also with the fact that for many the investment in pesticides is not worth the input, suggesting a trajectory of marginalization.

Differences between the two case studies may be associated with the form of capital involved: as farm scale and OHI findings show, on Lemnos, livestock capital was more suitable for intensification (change of breeds, increase in feed import) than olive trees where marginalization and niche markets seem to offer a better response to declining olive prices. Fetzel et al. (2018) discuss the example of another Greek island, Samothraki, where livestock intensification resulted in overgrazing as a response of local farmers to the CAP, but also to mega-trends such as the global crisis of the 2010s. This is in line with a recent study on farm resilience using the European Farm Accountancy Data Network, where for livestock and mixed farms authors found that decoupled payments increase farm adaptability (Slijper et al., 2021). Also, Terres et al. (2015) suggest that a “weak land market” increases the risk of land abandonment. This was confirmed in our study, where we saw that leasing as the main form of land tenure seems to contribute to flexibility in farmers’ decisions in Lemnos, which is portrayed by a low fluctuation of changes in the landscape. Similarly, Lidzhegu and Kabanda (2022) report declining farm resilience in South Africa due to urban pressures and land use management systems that do not support small scale farming (see also Netshipale et al., 2022). On Lesvos, the land market is less dynamic, which correlates with more land abandonment at the landscape scale.

As mentioned above, farmers’ choices may not apply to all the areas of the farm but affect some fields, while other fields may go into a different direction. This is one of the reasons for the mismatch between farm and landscape level findings: that intensification (or some other trajectory) may be practiced in some of the fields of the farm, while others are abandoned. Another reason may be more perceptive and related to how farmers tend to think and report on practices and inputs: persistence, or very little changes to their practices, does not feel like what they actually do in their farms. This is probably why in both case studies persistence was the basic outcome from the analysis at the landscape level but very few farms have reported persistence in the farm scale level. Finally, there is a difficulty in detecting many of the changes associated with intensification in the case studies from remote sensing data: the appearance and the dominant land cover is very similar, even if the inputs increase or decrease (Malek and Verburg, 2017).

The farm level illuminates the processes that lead to abandoning the whole farm or some fields while the rest of the farm is kept operational (Heider et al., 2021; Levers et al., 2018; Petanidou et al., 2008; Pliening et al., 2016; Terres et al., 2015; Ustaoglu and Collier, 2018). These different options are encountered in our case studies, although in this study we did not interview farmers that have abandoned farming altogether (unlike Zagaria et al., 2018 in the same area of Lesvos). The rationales offered are similar and many focus on succession, therefore even if some people may want to continue to farm all their fields and still earn money doing so, the lack of successors makes them slowly adapt to a retired farming style, more evident on Lesvos, as olive groves demand less care on an everyday basis compared to sheep husbandry (see also Wolpert et al., 2020). In addition, most of the olive trees are owned, so there is less need to extract a minimum profit from them each year, as opposed to leased land. Others do not find farming profitable anymore and keep smaller farms in more pluriactive household survival strategies (see also Kizos et al., 2011 for an analysis for Greece).

4.3. Responses to mega-trends in less favored areas: is abandonment inevitable?

The effect of mega-trends on farm management rationalizations and decisions are evident. Despite the fact that farmers typically focus on personal issues (e.g. lack of successors), rather than abstract drivers such as “globalization” or “more open markets”, in our study some issues have been mentioned directly in oral history interviews. First and foremost, several respondents mentioned that competitive international markets keep local prices low, while costs continue to rise. These developments lead to tangible, local manifestations such as the switch to more productive, non-indigenous breeds and more fodder imports on Lemnos. More views from former farmers that have already abandoned farming would provide more depth. This is partly in line with the meta-analysis of Mediterranean farm systems by [Debolini et al. \(2018, p. 706–7\)](#), where abandonment is associated with extensification, but only intensification is associated with economic drivers “in particular the profitability of new or different agricultural/farming systems and the changes in market prices, mainly the price of production” (see also [García-Martín et al., 2021](#); [Wolpert et al., 2020](#)). Here, the opposite side of this seems to be the case, as abandonment on Lesvos is associated with (lack of) economic profitability. Further, the study of [Debolini et al. \(2018\)](#) reports social and technological drivers in connection with specialization and points out the importance of institutional drivers in regard to “the existence of subsidies for some specific farming systems, local policies for supporting farmers and European policies”.

At the landscape level, the configuration of these different trajectories shows that we may have the same or similar trends on both case studies, but different landscape outcomes (see also [Dimopoulos and Kizos, 2020](#) for Lemnos and [Bürgi et al., 2017](#) for Lesvos). The type of land use seems to be important for only a fraction of these differences: responses of farmers suggest attachment to livestock farming and olive cultivation, which as earlier studies suggest are parts of local identities and considered as family assets and not just cultivations ([Gennai-Schott et al., 2020](#); [Zagaría et al., 2018](#)). The type of investments required may also make attachment to olives slightly more important, as olive trees may need up to ten years or more before they produce full yields. But olive trees require less labor than animal husbandry and can be managed “at leisure” by part-time farmers ([Wolpert et al., 2020](#)). Animal husbandry, on the other hand, requires everyday labor, is harder physically and therefore has to be practiced full time by “professional” farmers. This seems to affect succession patterns as well, although in a way less obvious than expected: more farmers on Lemnos reported having a successor than Lesvos, exactly due to this difference in labor and full-time requirements.

4.4. Implications for policy making: what are possible responses?

The case studies sites are in marginal Mediterranean landscapes that are currently at the intersection of agricultural abandonment, conservation of cultural landscapes and intensification ([García-Martín et al., 2021](#)). With focus on land abandonment, two different takes can be currently identified in policies according to [Dolton-Thornton \(2021\)](#). On one hand, land abandonment is environmentally detrimental due to the loss of farmland-related biodiversity and an increase in invasive species. In terraced landscapes, such as on Lesvos, land abandonment and degradation of terraces also increases the risk of soil erosion ([Koulouri and Giourga, 2007](#)). On the other hand, land abandonment may come with key environmental benefits, due to an increase in non-farm-linked biodiversity; ecosystem restoration, as well as carbon sequestration. It is hence criticized that often policies mainly have an agri-environmental focus, while land abandonment is actually “one particular branch of the large and multifaceted challenge of rural depopulation in Europe” ([Dolton-Thornton, 2021](#): p. 1). In our study, this is particularly evident in Lesvos, where respondents speak of a declining young population and diminishing rural infrastructure. Even though migration is related to the

low economic prospects of olive cultivation, the general lack of perspectives in the rural parts of the island is a problem that affects the whole region. In another study in the Ionian islands, evidence suggests that population recovery and tourism development resulted in recultivation of a significant proportion of the abandoned olive orchards ([Kefalas et al., 2018](#)). We therefore agree with [Dolton-Thornton \(2021\)](#) that it is crucial not to focus only on individual farms when it comes to addressing rural exodus, but to work with regional, holistic rural development programs.

[Fayet et al. \(2022a\)](#) point out “three main areas of tension”: the lack of recognition of abandoned lands in EU policy frameworks; the lack of policy alignment between biodiversity, climate change and agriculture/rural development policies; and the importance of spatial planning. The increase of the recognition of abandoned lands in EU policies is indeed an area where more integrated policies that can link agricultural policies, rural development policies and biodiversity and/or climate change with explicit mentions of the “potential of abandoned land for trajectories beyond farming”. They advocate for “a better balance between policy objectives” that “would help reconnect farmers with the EU policy level, reduce tensions and increase synergies between agricultural and biodiversity policies”. Their vision for policies that would essentially embrace abandoned land trajectories that do not focus on agricultural production to engage in conservation/restoration, with a focus on rural development and stronger reliance on land planning.

Our findings further shed light on some of the complexities involved, with different responses and outcomes even in areas that from a European and global point of view ([García-Martín et al., 2021](#)) are very similar environmentally, and share very similar socioeconomic developments in terms of economic change and rural depopulation. Identifying these different responses and outcomes are key to successfully building rural development programs that need to go beyond the agricultural sector and paint a more comprehensive picture of rural livelihood and development opportunities. For the development of such programs, a participatory rural planning process is proposed that actively involves local stakeholders to ensure suitability and co-responsibility ([Menconi et al., 2017](#)). Summing up, our findings highlight the complexity and mix of local drivers and global trends that drive abandonment in both the field and the landscape levels and guide the formulation and application of agricultural policies and public resources.

5. Conclusions

The agricultural landscapes of Europe are changing rapidly. Technological transformation and intensification are matched by abandonment in less competitive, marginal areas and areas where metropolitan areas expand. Our case studies demonstrate that marginalization and abandonment is one of the different responses encountered during this ongoing process. Though both of our study sites had similar contexts (remoteness and depopulation) and were thus also predicted to have the same high levels of land abandonment according to recent European land use models, our in-depth analysis using aerial photograph analysis and farmer interviews revealed that land abandonment was widespread on Lesvos but not on Lemnos. The diverging responses were due to the different opportunities for adapting to the challenges of globalized markets on the two islands. While livestock and arable farming systems on Lemnos were able to intensify and specialize to increase their competitiveness, the difficult terrain and longevity of olive trees on Lesvos limited the option space for intensification. Instead, our analysis showed that marginalization and niche markets (such as converting to organic) were more popular on Lesvos. The context-dependency observed in this study is particularly relevant when our case studies are placed within a European and global context: regionality is very important, but even within comparative spatial and environmental contexts, many variations along the main themes are met.

Another question that arises is how we should respond to

abandonment. Abandonment has been viewed both positively and negatively in environmental terms, but it is part of deep socioeconomic changes that are considered a problem and have to be addressed. Can it be reversed? In our study we observed both intensification and niche market specialization, especially the adoption of organic farming, as farm-level strategies to prevent marginalization. The success of strategies at the farm level is highly dependent on policies that address marginalization at the regional level: transport policies that increase accessibility, social policies that improve what is considered as quality of life in the area, and agricultural policies that either support farming through additional payments and/or provide assistance for improving the structures and the equipment of farms. Assessing their effectiveness is troubled by the lack of areas where these have not been applied to compare against areas where they have. Such policies have to target local responses to mega-trends, as these trends cannot be contained, but their effects could be ameliorated. As our cases reveal though, local responses may vary and this leads to the need to design policies that can be flexible enough to be effective in a variety of different contexts.

CRedit authorship contribution statement

Thymios Dimopoulos: Conceptualization, Writing – original draft, Writing – review & editing. **Julian Helfenstein:** Methodology, Writing – original draft, Writing – review & editing. **Amelie Kreuzer:** Investigation, Writing – original draft, Writing – review & editing. **Franziska Mohr:** Methodology, Writing – original draft, Writing – review & editing. **Stratis Sentas:** Investigation, Validation. **Rafail Giannelis:** Investigation, Validation. **Thanasis Kizos:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Data Availability

Data will be made available on request.

Acknowledgments

We thank all farmers who participated in the study. We are also grateful to Beatrice Schüpbach for conducting the NDVI analysis. The farmer survey was part of a pan-European survey using the same questionnaire in 14 case study sites across Europe. The experimental design and questionnaire received ethical clearance from the Ethical commission of the Swiss Federal Institute of Technology (ETH-EK 2020-N-146). The study was conducted as part of the project “What is Sustainable Intensification? Operationalizing Sustainable Agricultural Pathways in Europe (SIPATH)”, funded by the Swiss National Science Foundation (Grant no. CRSII5_183493). The study contributes to the Global Land Programme (GLP) science plan.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.landusepol.2022.106435](https://doi.org/10.1016/j.landusepol.2022.106435).

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